

NUEXCO

APRIL 1985

NUMBER 200

MONTHLY REPORT

ON THE NUCLEAR FUEL MARKET

NUEXCO

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MONTHLY REPORT ON THE NUCLEAR FUEL MARKET

April 1985

No. 200

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PRICING

Natural Uranium and Conversion	1
Enriched Uranium and SWUs	1

CURRENT MARKET DATA

Nuexco Market Data Table	3
Prices Expressed in Selected Currencies	4
Recent Transactions	6
Supply and Demand Tables	8

ANALYSIS AND COMMENTARY

Privatization and the Competitiveness of US Enrichment Services	13
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RECENT DEVELOPMENTS

Greece	18
Japan	18
United States	19

RAW MATERIALS

Uranium Deposits in the USSR	21
------------------------------------	----

HISTORICAL MARKET DATA

Graph of Exchange Value and Transaction Value	26
Historical Exchange Value, Transaction Value and Conversion Value ...	27

GOVERNMENT STATISTICS

Australia and Canada	28
South Africa and United States	29

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To Our Readers

Nuexco has just mailed a 1984 Annual Review to our full-service subscribers. This 54-page special report covers nuclear fuel market developments throughout the world in 1984 and early 1985. In particular, it analyzes the condition and pricing trends of the spot/near-term markets for uranium and secondary market enrichment services. Nuexco market values for 1984 have also been brought together in a series of tables for reference.

If you would like to purchase copies of the 1984 Annual Review Special Report, they are available for \$175 each. Please contact our Headquarters:

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PRICING

NATURAL URANIUM AND SECONDARY MARKET CONVERSION

The **Exchange Value** as of March 31, 1985 is **\$15.00** per pound U_3O_8 , unchanged since last month. **Active supply** of natural uranium (U_3O_8 and UF_6) for spot or near-term delivery totals **4,250,000** pounds equivalent U_3O_8 as concentrates or UF_6 , down 20 percent since last month. The corresponding figure for **active demand** is **4,055,000** pounds, up 80 percent. The spot and near-term **supply-demand ratio** fell to **1.0:1**.

The **Current Market Data** section of this Report lists eleven natural uranium sales transactions, involving a total of approximately 2,100,000 pounds equivalent U_3O_8 . Three of the transactions reported this month involved natural UF_6 , all involved deliveries before 1986, and ten met the criteria for inclusion in the current Transaction Value calculation.

The **Transaction Value** as of March 31, 1985 is **\$15.05** per pound U_3O_8 , down \$0.65 since last month. The current Transaction Value includes 16 transactions involving a total of 2.4 million pounds U_3O_8 or equivalent UF_6 and covers a period of 3 months. The Transaction Value fell as a result of the large number of transactions added to the calculation this month, allowing the removal from the calculation of two months' transactions involving over one million pounds of uranium. Those transactions, most of which took place at the end of 1984, involved prices consistent with the slightly higher Exchange Values (\$15.50 and \$15.25) of those months.

The **Loan Use Charge Rate** as of March 31, 1985 is unchanged at **5 percent** per annum, as a lender continued to offer a substantial quantity of material at that rate.

* * *

The uranium market was unusually active in March. Transactions continued to take place slightly above and below the \$15.00 level, and there were few indications of major price firming. Small quantities of material tended to command lower prices, but there was enough activity on both sides of the market to keep the Exchange Value temporarily stable. The heightened level of buyer interest has halted the slow decline of prices that was underway at the end of 1984.

* * *

The **Conversion Value** is **\$1.00** per pound U in UF_6 , unchanged since last month. One secondary market conversion transaction is reported, involving approximately 100,000 to 300,000 pounds U in UF_6 . Active supply of secondary market conversion services for delivery within

three years totals 110,000 pounds U as UF_6 . Active secondary market demand for conversion amounts to 255,000 pounds U in UF_6 .

It is becoming more and more difficult to characterize the secondary conversion market with only one price. Two distinctly different combinations of buyer-seller motivations are making two apparently conflicting types of pricing strategies necessary for the completion of transactions.

1. Sellers of natural UF_6 find it necessary to offer discounts of 25 to 35 percent (off the Nuexco Conversion Value) on the conversion component of their material in order to stimulate buyer interest.

2. Conversely, buyers that want secondary market conversion services (as opposed to UF_6) need to pay as much as a 50-percent premium (on the Nuexco Conversion Value) to attract a willing seller. Only one seller of conversion services is actively in the market at present, yet there are several buyers.

Thus, the conversion component contained in UF_6 is anywhere from one-half to three-fourths the value of conversion services purchased on the secondary market. That such apparently contradictory situations are present in the market is testimony to the degree of imperfection in the nuclear fuel market, imperfection which is most severe in conversion, the interface between U_3O_8 and UF_6 . In theory, the value of UF_6 should be equal to the sum of its U_3O_8 and conversion components. However, under the present market conditions, that equality does not hold. In fact, UF_6 is worth *less than* the sum of its constituents. Hence the need for UF_6 sellers to discount conversion, while conversion buyers need to pay a premium.

ENRICHED URANIUM AND SWUS

The Nuexco **SWU Values** as of March 31, 1985 are:

1. For **DOE origin**, a tails assay of 0.30 weight-percent U_{235} , and certifiable as excess:
 - a. For FY85 delivery, \$98 per SWU, down 4;
 - b. For FY86 delivery, \$25 discount from the USEC base price on delivery (20 last month);
2. For **other SWUs** (includes DOE origin SWUs not certifiable as excess and non-DOE origin SWUs):
 - a. For delivery in calendar year 1985, \$80 per SWU, unchanged;
 - b. For delivery in calendar year 1986, \$85 per SWU, down 3.

PRICING

One secondary market SWU transaction is reported, involving approximately 300 to 600 thousand SWUs of Eurodif origin.

* * *

The continuing drop in the value for SWUs certifiable as excess for delivery in fiscal year 1985 reflects the almost complete lack of active demand for FY85 material. One active buyer remains, and the rest of the SWU demand has shifted to the FY86 market as it continues to develop. DOE's announcement of FY86 SWU prices is expected in the coming weeks. In the meantime, the DOE market remains glutted with sellers, applying downward pressure on prices. There is still little activity in Europe in the market for other SWUs (non-DOE or DOE SWUs not certifiable as excess). Buyers can expect prices to fall in response to DOE's offer of incentive prices for SWUs purchased for delivery in 1987 and beyond.

At the beginning of April, DOE sent letters to USEC customers proposing an incentive pricing program for enrichment. Responses in the form of bids are due April 30, 1985. Acceptance of the bids is contingent upon a large-enough response to make the program viable: perhaps as much as 2,000,000 SWUs. As reported in last month's pricing section (Report 199, March 1985), FY87 and FY88 SWUs will be priced at \$90 per SWU (fixed), and FY89

and FY90 SWUs will be priced at \$90 per SWU (escalated from October 1, 1988 according to the escalation formula specified in Article 4 of the USEC). Utilities will be able to purchase incentive-priced SWU for FY87-88 or for FY87-90. Other details are as follows:

1. The customer must commit to buy 100 percent of uncommitted requirements under the incentive pricing arrangement.

2. The customer may purchase more than 30 percent of requirements if that opportunity was created by a contract termination that occurred before December 31, 1983.

3. Less than 30 percent of requirements may be purchased if the opportunity to do so is a result of a contract agreed to before February 15, 1985.

4. The Variable Tails Assay Option (VTAO) may be selected between 0.2 and 0.3 percent by the utility *at no charge*. Presumably, the customer will be required to give notice according to the period established in the USEC. The customer may select only one tails assay per SWU order.

Because the utilities are required to bid to DOE, Nuexco expects that some customers will bid back different terms to DOE in order to obtain the best deal possible. It is not known whether DOE will extend the response period past the April 30 deadline.

CURRENT MARKET DATA

March 31, 1985	Market Values	Active Supply ¹ (thousands)	Active Demand ¹ (thousands)
EXCHANGE VALUE	\$15.00/lb. U ₃ O ₈	4,250	4,055
CONVERSION VALUE	\$1.00/lb. U in UF ₆	110	255
SWU VALUES			
DOE origin, certifiable as excess, 0.3 tails assay			
FY85 delivery	\$98/SWU		
FY86 delivery	\$25 discount/SWU		
Other SWUs (non-DOE or non-certifiable)			
calendar year 1985 delivery	\$80/SWU		
calendar year 1986 delivery	\$85/SWU		
LOAN USE CHARGE RATE	5%/annum	0	0

TRANSACTION VALUE	\$/lb. U ₃ O ₈	Millions of Pounds	Number of Transactions	Number of Months
	15.05	2.4	16	3

¹Supply and demand tables in the *Current Market Data* section of this Report detail the numbers for each category.

DEFINITIONS

- The **Exchange Value** is Nuexco's judgment of the price at which transactions for significant quantities of natural uranium concentrates could be concluded as of the date indicated.
- The **Conversion Value** is Nuexco's judgment of the price at which spot and near-term transactions for significant quantities of conversion services could be concluded in the secondary market as of the date indicated.
- The **SWU Values** represent Nuexco's judgment of the price at which transactions for the sale of significant quantities of SWUs of stated origin for delivery in the specified time period could be concluded as of the date indicated.
- The **Loan Use Charge Rate** is Nuexco's judgment of the annual interest rate at which uranium loans could be concluded as of the date indicated.
- The **Transaction Value** is a weighted average price of recent natural uranium sales transactions. The calculation is based on prices paid in:
 - Transactions closed within the previous three-month period for which delivery is scheduled within one year of the transaction date;
 - At least ten transactions;
 - Transactions involving a sum total of at least 2 million pounds U₃O₈ equivalent.

The sample time is extended as necessary to include these minima. Other currencies are converted to US dollars using conversion rates in effect on or near the transaction date.

DERIVATIONS AND COMMENTS

- All Market Values are based on:
 - Data from recently completed transactions.
 - Data from pending transactions.
 - Firm bids to buy or borrow, and firm offers to sell or lend.
 - Prices purchasers or rates borrowers have expressed a willingness to pay, but for which Nuexco is not aware of firm bids to buy or borrow, and prices sellers or rates lenders have expressed a willingness to offer, but for which Nuexco is not aware of firm offers to sell or lend.
- Prices associated with deliveries under old or renegotiated contracts or other than arm's-length transactions are not considered in the determination of these Market Values.
- In the determination of the Conversion Value, Nuexco does not consider transportation charges other than those customarily provided by primary suppliers of conversion services.
- The prices of conversion services or SWUs delivered under long-term contracts with primary suppliers are not considered in the determination of either the Conversion Value or SWU Value.
- For the DOE SWU Values, Nuexco converts SWU prices at varying tails and product assays to equivalent SWU prices at a tails assay of 0.30 weight-percent U₂₃₅ and a product assay of 3.0 weight-percent U₂₃₅, assuming feed costs corresponding to the Nuexco Exchange and Conversion Values determined as of the same date.
- In calculating the Transaction Value, Nuexco does not account for the price of uranium delivered in connection with contracts which call for "market price" mechanisms. This exclusion applies particularly to contracts in which delivery prices are expressed as a function of future Exchange Values or any other indeterminate variable. Also excluded from the calculation are any other transactions in which the delivery price is defined in such a way that it cannot currently be determined.

NUEXCO

CURRENT MARKET DATA

EXCHANGE VALUE EXPRESSED IN SELECTED PRODUCER & CONSUMER CURRENCIES¹

Country (currency)	per lb. U ₃ O ₈ in Concentrates			per kg. U in Concentrates		
	This Month (Mar. 31, 1985)	Last Month (Feb. 28, 1985)	12 Months Ago (Mar. 31, 1984)	This Month (Mar. 31, 1985)	Last Month (Feb. 28, 1985)	12 Months Ago (Mar. 31, 1984)
Australia (dollar)	21.28	20.76	18.12	55.31	53.97	47.11
Belgium (comm. franc)	940.44	1,001	905	2,445	2,602	2,353
Canada (dollar)	20.53	20.73	21.73	53.38	53.89	56.50
Finland (markka)	97.66	103.38	94.34	253.88	268.76	245.26
France (franc)	143.13	152.39	135.24	372.11	396.19	351.60
FRG (mark)	46.90	49.85	43.92	121.94	129.60	114.17
Italy (lira)	29,922	30,902	27,490	77,791	80,339	71,469
Japan (yen)	3,793	3,881	3,805	9,860	10,090	9,892
Netherlands (guilder)	52.80	56.24	49.53	137.26	146.22	128.78
South Africa (rand)	28.71	30.00	21.01	74.63	77.99	54.63
Spain (peseta)	2,610	2,745	2,518	6,786	7,137	6,547
Sweden (krona)	135.01	140.71	130.87	351.00	365.82	340.23
Switzerland (franc)	38.88	42.37	36.37	101.08	110.16	94.56
UK (pound)	12.20	13.76	11.71	31.72	35.78	30.43
US (dollar)	15.00	15.00	17.00	39.00	39.00	44.20

TRANSACTION VALUE EXPRESSED IN SELECTED PRODUCER & CONSUMER CURRENCIES¹

Country (currency)	per lb. U ₃ O ₈ in Concentrates			per kg. U in Concentrates		
	This Month (Mar. 31, 1985)	Last Month (Feb. 28, 1985)	12 Months Ago (Mar. 31, 1984)	This Month (Mar. 31, 1985)	Last Month (Feb. 28, 1985)	12 Months Ago (Mar. 31, 1984)
Australia (dollar)	21.35	21.73	20.52	55.50	56.49	53.34
Belgium (comm. franc)	943.57	1,047	1,025	2,453	2,723	2,665
Canada (dollar)	20.60	21.70	24.61	53.56	56.41	63.97
Finland (markka)	97.98	108.20	106.83	254.73	281.30	277.72
France (franc)	143.61	159.50	153.14	373.35	414.68	398.14
FRG (mark)	47.06	52.18	49.73	122.35	135.65	129.28
Italy (lira)	30,022	32,344	31,129	78,050	84,088	80,928
Japan (yen)	3,805	4,062	4,308	9,893	10,561	11,201
Netherlands (guilder)	52.97	58.87	56.09	137.72	153.04	145.82
South Africa (rand)	28.80	31.40	23.79	74.88	81.63	61.86
Spain (peseta)	2,619	2,873	2,851	6,808	7,470	7,413
Sweden (krona)	135.46	147.28	148.19	352.17	382.89	385.26
Switzerland (franc)	39.01	44.35	41.19	101.42	115.30	107.07
UK (pound)	12.24	14.40	13.26	31.82	37.45	34.46
US (dollar)	15.05	15.70	19.25	39.13	40.82	50.05

¹ Calculated using currency exchange rates published in the *Wall Street Journal* on March 29, 1985.

CURRENT MARKET DATA

CONVERSION VALUE EXPRESSED IN SELECTED PRODUCER & CONSUMER CURRENCIES¹

Country (currency)	per lb. U as UFs			per kg. U as UFs		
	This Month (Mar. 31, 1985)	Last Month (Feb. 28, 1985)	12 Months Ago (Mar. 31, 1984)	This Month (Mar. 31, 1985)	Last Month (Feb. 28, 1985)	12 Months Ago (Mar. 31, 1984)
Australia (dollar)	1.42	1.38	0.85	3.13	3.05	1.88
Belgium (comm. franc)	62.70	66.71	42.60	138.22	147.07	93.91
Canada (dollar)	1.37	1.38	1.02	3.02	3.05	2.25
Finland (markka)	6.51	6.89	4.44	14.35	15.19	9.79
France (franc)	9.54	10.16	6.36	21.04	22.40	14.03
FRG (mark)	3.13	3.32	2.07	6.89	7.33	4.56
Italy (lira)	1,995	2,060	1,294	4,398	4,542	2,852
Japan (yen)	252.84	258.73	179.05	557.43	570.41	394.74
Netherlands (guilder)	3.52	3.75	2.33	7.76	8.27	5.14
South Africa (rand)	1.91	2.00	0.99	4.22	4.41	2.18
Spain (peseta)	174.00	183.02	118.50	383.61	403.48	261.25
Sweden (krona)	9.00	9.38	6.16	19.84	20.68	13.58
Switzerland (franc)	2.59	2.82	1.71	5.71	6.23	3.77
UK (pound)	0.81	0.92	0.55	1.79	2.02	1.21
US (dollar)	1.00	1.00	0.80	2.20	2.20	1.76

SWU VALUES EXPRESSED IN SELECTED PRODUCER & CONSUMER CURRENCIES¹

Country (currency)	DOE SWU FY85 (March 31, 1985)	Non-DOE SWU 1985 delivery (March 31, 1985)	Non-DOE SWU 1986 delivery (March 31, 1985)
Australia (dollar)	139.01	113.48	120.57
Belgium (comm. franc)	6,144	5,016	5,329
Canada (dollar)	134.15	109.51	116.36
Finland (markka)	638.02	520.83	553.39
France (franc)	935.11	763.36	811.07
FRG (mark)	306.44	250.16	265.79
Italy (lira)	195,492	159,585	169,559
Japan (yen)	24,779	20,228	21,492
Netherlands (guilder)	344.95	281.59	299.19
South Africa (rand)	187.56	153.11	162.68
Spain (peseta)	17,052	13,920	14,790
Sweden (krona)	882.09	720.07	765.08
Switzerland (franc)	254.02	207.36	220.32
UK (pound)	79.71	65.07	69.13
US (dollar)	98.00	80.00	85.00

¹Calculated using currency exchange rates published in the *Wall Street Journal* on March 29, 1985.

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CURRENT MARKET DATA

RECENT TRANSACTIONS¹

Uranium Sales

Nuexco Transaction Number	Delivery Period	Approximate Quantity (thousands of pounds, U ₃ O ₈ equivalent)	Approximate Price as Percent of Current E.V.	Seller	Buyer	Remarks
3381	1985	less than 50	100	US Producer	US Producer	
3380	1985	less than 50	98	US Producer	US Producer	
3371	1985	601-1,000	R ²	US Utility	European Utility	UF ₆ . Inventory sale.
3370	1985	301-600	93	US Utility	European Utility	UF ₆ . Inventory sale.
3369	1985	101-300	93	US Utility	US Utility	UF ₆ . Inventory sale.
3367	1985	less than 50	94	US Producer	US Utility	
3364	1985	101-300	101	US Producer	US Producer	
3358	1985	301-600	98	US R ²	US R ²	
3356	1985	less than 50	97	US R ²	US R ²	
3346	1985	less than 50	94	Trader	US Utility	
3344	1985	less than 50	95	Trader	US Utility	

¹ Transactions listed are not limited to those in which Nuexco was involved, but also include others of which Nuexco is aware.

² The notation R means that Nuexco either does not know, or that Nuexco has restricted that information to protect client confidentiality.

CURRENT MARKET DATA

RECENT TRANSACTIONS¹ (continued)

Secondary Market Conversion Services

Nuexco Transaction Number	Delivery Period	Approximate Quantity (thousands of pounds, U equivalent)	Approximate Price as Percent of Current C.V.	Seller	Buyer	Remarks
3357	1985	101-300	65	R ⁵	US Utility	

Enrichment Services

Secondary Market Sales

Nuexco Transaction Number	Delivery Period	Approximate Quantity ² (thousands of SWUs)	Approximate Price ³ as Percent of Current SWU Value ⁴	Seller Group	Buyer Group	SWU Origin	Remarks
3341	1986-1988	301-600	see remarks	European Entity	US Utility	Eurodif	Series of fixed prices.

¹ Transactions listed are not limited to those in which Nuexco was involved, but also include others of which Nuexco is aware.

² If tails assay is unknown or unspecified, Nuexco's calculation of SWU quantity assumes 0.30 w/o tails assay.

³ Price is not normalized to 0.30% tails assay.

⁴ Refers to SWU Value that corresponds to SWUs included in transaction. When prices and SWU values are expressed as discounts (e.g., X dollars less than DOE's USEC base price at time of delivery), the percentage refers to the ratio of the discounts, not the ratio of the prices.

⁵ The notation R means that Nuexco either does not know, or that Nuexco has restricted that information to protect client confidentiality.

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CURRENT MARKET DATA

URANIUM SUPPLY (March 31, 1985)

Nuexco Project Number	Delivery Period ¹ (Thousands of Pounds U ₃ O ₈)		Remarks
	Spot or Near-term ²	Intermediate or Long-term	
Available for Sale:			
ACTIVE			
1575	500	500 per year	
1860	400	1,500 per year	
2134	220	220 per year	1986-87
2389	200	—	
2392	35	—	UF ₆
2538*	15	—	
2565	400	—	
2574*	640	—	
2584*	5	—	
2633	1,800	—	
2675	35	—	UF ₆
.....			
2263	—	500 per year	1985-90
2625	—	250 per year	1987-89
2657	—	980	1986; UF ₆
2680*	—	250 per year	1986-92
.....			
TOTAL:	4,250		
INACTIVE			
2191	125	—	UF ₆
2275*	170	—	
2335	275	—	
2336	250	250 per year	1985-94
2495	130	—	UF ₆
2553	300	—	
2654*	250	250 per year	UF ₆
.....			
2271	—	500 per year	1985-88
2297	—	200 per year	1986-89
2368	—	250 per year	1987-90
2670	—	525	1987
.....			
TOTAL:	1,500		

* New or revised since last month.

¹ Measured from the date of this Report.

² For delivery within one year. This category excludes material deliverable within one year under other than spot or near-term contracts.
Projects removed since last month: 0564, 2038, 2288A, 2288B, 2499, 2514, 2603, 2650.

NUEXCO

Page 9
April 1985
#200

CURRENT MARKET DATA

URANIUM DEMAND (March 31, 1985)

Delivery Period ¹ (Thousands of Pounds U ₃ O ₈)			
Nuexco Project Number	Spot or Near-term ²	Intermediate or Long-term	Remarks
Inquiries to Purchase:			
ACTIVE			
2419*	130	—	UF ₆
2548*	290	—	
2574B*	640	—	UF ₆
2590*	75	—	U ₃ O ₈ or UF ₆
2636	100	—	
2659*	250	—	
2661	260	260 per year	1986-87
2674*	800	—	
2676*	100	—	UF ₆
2690	160	—	
2995*	1,250	—	UF ₆
2217	—	1,000 per year	1989-95
2442	—	4,000	1986-95
2507	—	600	1987-89
2540	—	400 per year	1989-94
2611*	—	130 per year	1987-88
2681*	—	1,000 per year	1987-88
2694*	—	625	1987; UF ₆
TOTAL:	4,055		
INACTIVE			
2576	20	—	UF ₆
2244	—	350 per year	1987 on
2414	—	365	1987-88
2457B	—	650	1987
2586	—	300	1987
2643	—	150 per year	1987 on
TOTAL:	20		

* New or revised since last month.

¹ Measured from the date of this Report.

² For delivery within one year. This category excludes material deliverable within one year under other than spot or near-term contracts.
Projects removed since last month: 1999, 2329.

NUEXCO

CURRENT MARKET DATA

LOAN SUPPLY AND DEMAND (March 31, 1985)

Nuexco Project Number	Delivery Period ¹ (Thousands of Pounds U ₃ O ₈)		Remarks
	Within 1 Year	Beyond 1 Year	
Available for Loan:			
INACTIVE			
1938	2,000	—	UF ₆
2128	700	—	
2139	2,000	—	
2469A	800	—	
2483	550	—	
2667	800	—	
TOTAL:	6,850		

CONVERSION SUPPLY AND DEMAND (March 31, 1985)

Nuexco Project Number	Delivery Period ¹ (Thousands of Pounds U as UF ₆)		Remarks
	Within 3 Years	Beyond 3 Years	
Available for Sale:			
ACTIVE			
2051*	110	—	
TOTAL:	110		
INACTIVE			
2438	500	250 per year	1986-87
2511	600	700	1986-90
TOTAL:	1,100		
Inquiries to Purchase:			
ACTIVE			
2419A	55	—	
2602	200	—	
2617*		275	1986-91
TOTAL:	255		
INACTIVE			
2529	225	—	
2587*	70	—	
2644		475	1987 on
TOTAL:	295		

* New or revised since last month.

¹ Measured from the date of this Report.

Projects removed since last month: None

NUEXCO

Page 11
April 1985
#200

CURRENT MARKET DATA

SWU SUPPLY (March 31, 1985)

Nuexco Project Number	Delivery Period ¹ (Thousands of SWUs)		Remarks
	Spot or Near-term ²	Intermediate or Long-term	
Available for Sale:			
ACTIVE			
2100	150	100 per year	
2359*	—	200	
2624	100	—	
2631	150	—	
2633B	330	—	
2664	150	—	
.....			
2285	—	300	
2513	—	25	1986
2517*	—	155	1986-89
2571	—	55	1987

TOTAL:	880		
INACTIVE			
2164*	20	—	
.....			
2378	—	120	1988
2510	—	50	
2652	—	25	1986

TOTAL:	20		

* New or revised since last month.

¹ Measured from the date of this Report.

² For delivery within one year. This category excludes SWUs deliverable within one year under other than spot or near-term contracts.
Projects removed since last month: 2583, 2657A, 2689

NUEXCO

CURRENT MARKET DATA

SWU DEMAND (March 31, 1985)

Nuexco Project Number	Delivery Period ¹ (Thousands of SWUs)		Remarks
	Spot or Near-term ²	Intermediate or Long-term	
Inquiries to Purchase:			
ACTIVE			
2655	10	—	
2400*	—	150	1987-90
2519	—	30 per year	1987 on
2578	—	100	1986
2653	—	100	1986-90
2658	—	5	1986
TOTAL:	10		
INACTIVE			
2543	25	25	1986
2585*	—	40	1986
2500*	—	170	1988
2512	—	15 per year	1987 on
2595	—	50	1986
2693*	—	100 per year	1989-90
TOTAL:	25		

* New or revised since last month.

¹ Measured from the date of this Report.

² For delivery within one year. This category excludes SWUs deliverable within one year under other than spot or near-term contracts.
Projects removed since last month: 2665, 2669.

PRIVATIZATION AND THE COMPETITIVENESS OF US ENRICHMENT SERVICES

by Dr. Karl P. Cohen

The following is a presentation made by Dr. Karl Cohen at the Atomic Industrial Forum's Fuel Cycle Conference in New Orleans on March 13, 1985. Dr. Cohen's distinguished record in the field of nuclear energy includes major contributions to the theory of isotope separation and the methodology of gaseous diffusion and centrifugal separation. He received the 1979 Chemical Pioneer Award of the American Institute of Chemists for his theory of gas centrifuges. This presentation is reprinted by permission.

Introduction

In 1973, the US nuclear power program was projected to attain 1,200 GWe by the turn of the century. It is now projected to reach only 110 GWe (Table 1). The uranium enrichment industry, which presently has little other purpose than to supply fuel for nuclear power plants, must obviously be profoundly affected. We are not looking here at minor changes, which might be accommodated by a change in style of doing business, however desirable that might be. We are looking at order-of-magnitude changes. We are looking at an earthquake. What is called for is a complete reappraisal of the fundamental purposes and structure of the US uranium enrichment program, including our objectives in serving the domestic and inter-

national uranium enrichment markets by a government-managed enterprise.

You will have recognized that this call for a reappraisal of the goals of our enrichment program bears some resemblance to the conclusion of the Comptroller General in his recent report to former Congressman Ottinger on the new Utility Services Contract. There are however significant differences. I do not consider it *a priori* evident that serving the international market should be a primary objective, that pricing by itself will be sufficient to achieve it.

At present, fuel accounts for 20 to 30 percent of the generating cost of nuclear power (the lower value is in the USA, where capital costs are high). About one-third of this cost comes from the enrichment process. Thus enrichment contributes only 7 to 10 percent of nuclear power costs, while capital charges account for 50 to 70 percent. To a plant owner, assurance of supply of enriched uranium has five to ten times the economic weight as the price of enrichment itself. But the supply of enriched uranium from the USA is conditional on political concessions which are not only burdensome but subject to unilateral change. This has made the USA the enrichment supplier of last resort in the only market which still has vitality—the off-shore market. To breathe new life into the US enrichment enterprise we shall have to look at more than the technology, and more than the price. We shall have to examine some of the unwanted side-effects of that sacred cow of American politics, the nuclear non-proliferation policy.

The parallel between the difficulties of the enrichment enterprise and the difficulties of the US nuclear power industry has certainly not escaped this audience. The recent Forbes article concludes that a reform of our institutions, more than of our technology, is the prerequisite for a rebirth of the nuclear option in the US. Similarly, important as technology is in uranium enrichment, a purely technological fix is not available to us. We have to take into account the management of the enterprise, and the policies and institutions which constrain it.

Let me refer you back for a moment to the data in Table 1. It is clear that a pricing formula which might be perfectly reasonable in 1973 could be wildly inappropriate in 1985. The GAO letter, and the Congressional inquiry which precipitated it, illustrate, if further illustration were necessary, the intrinsic difficulties of government management of uranium enrichment, and the desirability of serious consideration of privatization.

Table 1

US ENRICHMENT ENTERPRISE CAPACITIES¹ (Millions of SWUs per year)

	1973	1985
Capacity	17	27
Planned Capacity	10	13
Production	10	10
Projected domestic market in the year 2000	100	12
Projected off-shore market in the year 2000	100	30
Off-shore market share in percent	100	37

¹Free World only.

ANALYSIS & COMMENTARY

Objectives

Table 2 presents a number of possible objectives for the enrichment enterprise. At first glance, it might seem that all the objectives are desirable, and that all can be attained. However, this is only possible in a monopoly situation. For example, the virtue of the first objective, assuring domestic fuel supply, seems almost self-evident. It is a parallel to the requirement of the Atomic Energy Act that a viable domestic uranium industry be maintained. But other countries, many of whom have a far greater percentage commitment to nuclear electricity than we do, are likely to think the same way. If we are prepared to pay more for uranium from low-grade American ore, will they not be willing to buy enrichment services from their local enrichers, even at a premium? Assurance of supply by supporting domestic producers is a doctrine which, if adopted universally, is likely to frustrate the achievement of Objective 4. The continued interest in new enrichment programs—for example, Japan, Brazil, South Africa and Argentina—despite the world glut of separation capacity and overhanging enrichment inventories, points in this direction.

Table 2
POSSIBLE ENRICHMENT ENTERPRISE
OBJECTIVES

1. Assure fuel supply for domestic reactors.
2. Maintain capability to produce HEU for military.
3. Maximize off-shore sales of reactor equipment by advantageous terms for enriched fuel.
4. Maximize off-shore market by low prices to support US non-proliferation policy.
5. Maximize market share by low prices to increase cash return.
6. Maximize profit.

The second objective introduces two new questions. The first is whether the production of HEU should ever be privatized. This might be resolved by splitting out the high enrichment cascade from the rest of the plant and retaining it as a separate, government-owned entity. This leads naturally to the issue of whether a privatized enrichment enterprise should be in one piece or split into several. Arguing for one piece are the extraordinarily high capital requirements of enrichment plants, capital which could

be raised on most favorable terms by a regulated monopoly. A regulated monopoly could write long-term exclusive contracts, also helpful in raising capital, without running afoul of the anti-trust laws. Arguing for several pieces are the benefits of competition, and the relative ease of introduction of new technology.

The last four objectives are somewhat inconsistent, since it is unlikely that one can maximize them simultaneously. During the period of American monopoly of uranium enrichment facilities, maximizing off-shore sales of nuclear reactors and supporting US non-proliferation policy were not obviously incompatible. However, American supply of enriched uranium was accompanied by restrictions on use or disposal of the spent fuel. These were not acceptable to the Europeans, and were a determining factor in our ultimate loss of the enrichment monopoly. The passage of the Nuclear Non-Proliferation Act of 1978, which contains clauses encouraging the use of solar and renewable energy rather than nuclear power, and discouraging the reprocessing and recycling of spent nuclear fuel, has effectively eliminated the third objective. Nobody can possibly believe that the object of the coalition that passed the Act was to foster nuclear power in any country. The present policy of DOE is a combination of objectives 4 and 5, namely, maximizing the market share by lowering prices, to increase cash flow and also to support US non-proliferation policy. Increasing cash flow is the driving force. Supporting non-proliferation policy is a constraint. It should be noted that the erosion of the US off-shore market share began *before* the rise of the dollar, while we still had price leadership. Thus the policy seems unlikely to succeed without ruinous price concessions. It reminds me of the legendary wholesaler who lost on each sale, but made it up on volume.

The last objective is maximizing profit. Unless this is taken as the primary objective, privatization is only a slogan, not a real option. Maximizing profit might require a very different approach to the market. The approach might be to set terms and prices to suit the domestic market (where there is a preference for US supply), rather than to obtain the maximum off-shore market; to shut down and write off excessive and high cost production facilities; to evaluate technical options on a total cost and not a forward cost basis; to control costs by eliminating excessive contractors and excessive personnel; and to share the benefits of lower cost advanced technologies by improving profits as well as lowering prices. Such an approach would require unified marketing, but could in the long run accommodate competitive producing units.

ANALYSIS & COMMENTARY

Further Observations on Privatization

The current invitation of DOE for private industry to invest in the AGC and the AVLIS processes is directed at solving DOE's immediate financial problem without altering the Department's management of the projects. The capital intensity of uranium enrichment is unusually great. The government is in fact the appropriate source of capital or credit. The financial problem has arisen by a combination of delayed management response to the rapidly changing market conditions, and hostile Congressional oversight. Industry has no place volunteering to be the lender of last resort, merely because ideologues in and out of Congress impose unreasonable constraints on the finances and the policies of the enrichment enterprise.

What should be privatized is not the *financing*, but the *management* of the uranium enrichment enterprise. This Administration, (and previous ones as well), have favored this procedure for organizations as diverse as the Post Office, the Federal National Mortgage Association, and the Tennessee Valley Authority.

The last major effort at privatization of enrichment peaked in the period 1975-76 with the debate on (and defeat of) the Nuclear Fuel Assurance Bill. At the time, the late Craig Hosmer suggested that a government corporation would be a more acceptable alternative. I believe his idea has considerable merit. Such a corporation would isolate the enrichment enterprise from the annual Congressional budget process. It could offer bonds like TVA, and allow investment to be offered based on the needs, and supported by the revenues, of the enrichment business alone. The Board of Directors should be larger than that of TVA, and include outside directors who would represent the insights and interests of other segments of the nuclear industry, notably (but not exclusively) the utilities and the uranium miners.

To establish such a corporation, new legislation would be necessary. The debate on such legislation would furnish an opportunity to forge a consensus on the *objectives* as well as the *structure* of the corporation, and might be an important step in the public education needed for a rebirth of the nuclear industry.

The Economic Competition

Economic comparisons between plants in different countries are very hazardous. Plant capital costs, even if fully reported, are in different currencies. Inflation and interest during construction depend on local circumstances and schedules. They are not strictly comparable, and they are seldom fully reported. The capital charge

rate applied depends on details of the financing, generally considered a commercial secret, and the local accounting rules. In the US enrichment plants, the capital charge is the imputed interest rate, which rises and falls from year to year with general interest rates. Inventories of natural and enriched uranium may be large or small, depending on policy and history. The inventories may be valued at acquisition costs (themselves variable), or otherwise. The cost of maintaining inventory may be calculated in the same way as the cost of fixed capital, or differently. Finally the utilization factor—the fraction of the plant capacity which is actually used—is an overall divisor into the capital charges.

Of the operating costs, labor rates and productivity vary from one country to the next. In the gaseous diffusion process, the pricing formulae reveal that half the price is proportional to the cost of power. The power costs depend on contract arrangements with particular suppliers, whose demand and energy charges are not uniform. While these are published in the US, they are not readily available elsewhere. Plant managers, depending on production requirements, may schedule operations at off-peak hours, thus obtaining better rates. Thus, Eurodif plans to operate only during the seven summer months when power costs are lower.

Translating costs from one currency to another introduces another uncontrollable factor. Over the past four years the dollar has risen approximately 40 percent against a basket of 15 foreign currencies, and even more spectacularly—150 percent—against the French franc. Most observers believe the dollar is at a cyclical high and will come down. I do not know of any accepted economic theory which defines "equilibrium" exchange rates, but it seems unlikely that the dollar will fall below its 1980-81 values, when it was at a cyclical low. In most of the economic comparisons, I use the low values, to show that our present lack of cost and price leadership will not disappear with the next exchange rate fluctuation.

It is clear that the long-range competitiveness of the US Gaseous Diffusion Plant is not determined by the temporary embarrassment of an unfortunate power contract which imposes high demand charges for power not used. Just as clearly, it cannot be measured by the price of a particular block of kWh purchased over a summer weekend. We must bring in more fundamental considerations. What appears to be really relevant is the average bus-bar cost of electric energy to all US industry. We must face the fact that the US utility industry has fallen behind the rest of the world in its ability to build new capacity@economy-

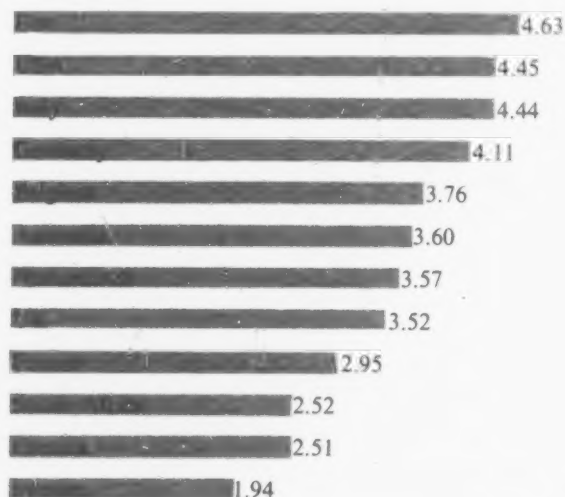
ANALYSIS & COMMENTARY

cally. The capital costs of any new generating capacity are so high that we are witnessing a virtual moratorium on new plant construction. In a situation where new capacity costs more than installed capacity, lower prices to one industry mean higher prices and less competitiveness for another.

When push comes to shove, the ultimate measure of competitiveness of gaseous diffusion plants will be their out-of-pocket costs for additional SWUs. Figure 1 shows the situation as of April 1, 1984. Eurodif uses about 13% more kWhs per SWU than our plants, but our kWhs cost about 50 percent more than theirs. Table 3 looks further ahead to 1990. Notice that the French total power cost is projected to be two-thirds of ours and their energy cost one-half, using 1981 exchange rates. In 1981, the franc was about 20 cents. The bottom line is my speculation on the generating costs of a Siberian hydro plant which would be feeding current to a Russian diffusion plant. The conclusion seems inescapable that our superior diffusion technology is not enough to compensate for the diffi-

Figure 1

WORLD INDUSTRIAL AND COMMERCIAL ELECTRICITY PRICES AS OF APRIL 1, 1984¹ (Pence per kilowatt-hour)



¹ This figure is a reproduction of a figure presented in *Nuclear Europe*, Volume 10, October 1984, in an article by G. Ekberg, L. Fogelstrom and L. Gustafsson entitled "Nuclear Power Production in Sweden." Source: National Utility Services.

culties of our power industry. We will not regain price leadership with an energy-intensive process.

Table 3

LEVELIZED DISCOUNTED GENERATION COSTS 1990 PLANTS (Jan. 1, 1981 cents per kWh) (discount rate 5 percent)

Country	Capital	O & M	Fuel	Total
France (Nuclear)	1.02	0.36	0.69	2.07
USA (Coal)	1.03	0.37	1.52	2.92
USSR (Hydro)	?	?	0.00	1.00

Source: OECD, September 9, 1983.

Table 4 gives the approximate status of the competition in centrifuge technology, given in 1980 dollars. In addition to the difficulties mentioned above of comparing costs in different countries, note that none of these plants has actually been completed and operated. Prudence suggests a further reserve about what the numbers will be when the plants are on-line. However, Urenco has already built and operated some plants, and half the Portsmouth plant is already in existence, so the rankings have some credibility. Let me remind you again that these rankings are in 1980 dollars. Since then, the mark has dropped from 50 cents to 30 cents. At present exchange rates, the German and American technologies would appear to be neck-in-neck.

I have not prepared a table on the economics of the AVLIS process, since I have no confidence in my ability to project the capital and operating costs of the process when (and if) it is realized. Since many other nations are,

Table 4

THE CENTRIFUGE COMPETITION (1980 dollars)

Technology	Capital \$ per SWU per year	Power \$ per SWU	O & M \$ per SWU
US Set III	660	2	22
Urenco 1985 ¹	500	2	11
US Set V	330	2	11

¹ Gronau, FRG.

ANALYSIS & COMMENTARY

as they should be, interested in laser isotope separation, I do not doubt that we shall face strong competition in this technology as well.

Conclusions

It is time for us to discard the notion, which is a hold-over from the years of American monopoly of uranium enrichment supply, that we have guaranteed technical superiority in all branches of isotope separation; and that this technical and economic superiority is so great that we can impose terms and conditions on our enrichment supply without regard to the preferences of our customers, or the alternatives available to them. We do have, indeed, the largest surplus enrichment capacity in the world, burdened with the highest energy costs. It is not plain why this is an advantage.

The last addition to the US gaseous diffusion plants increased the capacity over the years 1974 to 1982 by 10.1 million SWU per year, at a cost of 1.5 billion nominal dol-

lars. Over roughly the same period, Eurodif built a green field plant of 10.8 million SWU per year, at a cost of 16 billion francs. No matter how one translates from francs to dollars, this is a respectable achievement. The French have developed a chemical exchange process for uranium enrichment, which we were unable to do. The inventor of the basic design of the modern gas centrifuge is still consulting for Urenco. This is not a time for complacency, still less for cutting back on research and development, as I was horrified to see embodied in the justification furnished for our new contract price of \$135/SWU.

We also need, not *business-like* management, but *business management*, free to choose and fight for realistic goals, and free to make the hard decisions which will be required to implement them. In the long run, privatization will probably be required to achieve our objectives. Establishment of a government corporation is the essential first step.

RECENT DEVELOPMENTS

GREECE

The Greek Institute of Geological and Mining Research (IGME) has announced the existence of a uranium production pilot plant in Paranesti, in northern Greece. The plant's construction was funded jointly by the Greek government and the European Economic Commission (EEC), and has been in operation since November 1984. IGME conducts exploration in the area and operates the pilot plant.

IGME began extensive survey operations at Paranesti in 1980, although the existence of uranium deposits in the area was documented in the early 1960s. IGME has estimated reserves at several million tonnes, and plans to issue a revised reserves estimate in the coming months. While the government's official energy plan does not mention nuclear power, the Energy Minister stated that known uranium reserves are capable of providing fuel for a 600-MWe reactor for 35 years, and the issue was now under study.

JAPAN

Kansai Electric Power Co. recently completed the planning phase for two additional 1,180-MWe PWRs, Ohi Units 3 and 4, to be located at the current Ohi site. In its first approval action for new nuclear generation facilities in 22 months, the government's Electric Power Resources Development Coordination Council (EPRDCC) granted approval to plans for the two units and officially recognized them as projects (see Report 188, April 1984, for Japan's nuclear plant licensing procedure). Kansai Electric is now prepared to submit plant designs and safety analysis for construction/operating license approvals. Commercial operation dates for the two units are scheduled for 1991 and 1992, respectively.

Similar EPRDCC approval is expected shortly for Tokyo Electric Power's Kashiwazaki Units 3 and 4, each 1,100-MWe BWRs, with commercial operation scheduled for 1993 and 1994 respectively. Chubu Electric also announced it was planning its next plant, Hamaoka Unit 4, which probably will be an 1,100-MWe BWR. A commercial operation date for the plant has not been established.

* * *

Plans for location of new enrichment, reprocessing and low-level waste storage facilities at a common location are proceeding as scheduled (see Report 193, September 1984). The governor of Aomori Prefecture, the proposed location of the facilities, announced his approval of the

projects, subject to final endorsement by the prefectural assembly, expected by the end of March.

The Power Reactor and Nuclear Fuel Development Company (PNC), which developed centrifuge technology for the planned enrichment facility, also will provide reprocessing technology for the planned reprocessing facility, to be operated by Japan Nuclear Fuel Services (JNFS). PNC, under a national development program, has built and operated since 1980 an 0.7-ton-per-day demonstration reprocessing plant at Tokai Mura. The plant sustained a series of dissolver failures in 1982 and 1983, and has operated only intermittently. Dissolver repair and replacement programs recently were completed. The plant now is scheduled to return to normal operations in April. An initial goal to process 70 tons of spent LWR fuel from domestic reactors has been established. Several other developments in plans for recycling plutonium and depleted uranium have occurred in recent months:

1. Japan Atomic Power Company (JAPC) has received license approval to load two mixed-oxide fuel bundles into Tsuruga Unit 1, a 357-MWe BWR, for test purposes. In a separate study, government agencies have suggested that the utilities should plan to load mixed-oxide fuel into ten LWR units by 2000.

2. PNC successfully performed test enrichment of depleted uranium produced by its Tokai Mura reprocessing facility. PNC is proposing that the utilities support construction of a facility to re-enrich 20 to 100 tons of depleted uranium annually to demonstrate the technology.

3. PNC recently announced new cost estimates for its often-delayed, 280-MWe demonstration FBR now scheduled for operation in the mid-1990s. The current estimate exceeds \$2.3 billion, a 50-percent increase from the 1979 estimate.

* * *

Japanese utilities have concluded annual price negotiations for deliveries under long-term uranium supply contracts with African and European suppliers. The utilities agreed to pay approximately \$32 per pound U_3O_8 for 1986 deliveries (fiscal year ending March 31, 1986), a reduction of \$1.00 to \$1.50 relative to the price paid for 1985 deliveries.

The annual price negotiations are influenced greatly by developments in the spot and near-term prices over the previous year, as opposed to the months immediately preceding the negotiations. Thus, the spot/near-term prices paid in May or June 1984, when the Exchange Value was \$17.75, probably had as much influence in determining FY86 long-term prices as did spot/near-term prices paid

RECENT DEVELOPMENTS

in February or March 1984, when the Exchange Value was \$15.00.

The downward pricing trend for long-term price agreements has slowed considerably in the last few years, fall-

ing only \$3.50 since FY83. Table 5 shows a comparison for the past six years of annually negotiated prices versus average Exchange Values, which have declined at a much greater rate.

Table 5
RESULTS OF ANNUAL JAPANESE URANIUM PRICE NEGOTIATIONS
COMPARED TO EXCHANGE VALUE

Fiscal Year Ending March 31	Approximate Agreed Price (\$/lb. U ₃ O ₈)	Average E.V. for Preceding Japan FY (1980-85) (\$/lb. U ₃ O ₈)	Delivery Price/ Average E.V.
1981	45.00	41.17	1.1
1982	37.75	28.63	1.3
1983	35.50	23.65	1.5
1984	33.70	19.65	1.7
1985	33.50	22.10	1.5
1986	32.00	16.44	1.9

UNITED STATES

Several NRC reactor licensing actions took place in the last few months. Middle South Utilities, Inc. received a full-power license for its Waterford plant, a 1,104-MWe PWR. Commonwealth Edison received a low-power license for its Byron Unit 1, the first of two 1,120-MWe PWRs at the site. Kansas Gas and Electric Co. received a fuel-loading and low-power-testing license for its Wolf Creek plant, a 1,150-MWe PWR. Detroit Edison also received a fuel-loading and low-power-testing license for its Fermi Unit 2. Commercial operation for all four units is expected in 1985. In addition, Diablo Canyon Unit 1 reached 100-percent power in March, and is delivering 1,100 MW to the Pacific Gas & Electric grid. An inquiry by the California Public Utilities Commission has begun to determine how much of the \$4 billion plant should be allowed into the rate base.

On the negative side, the low-power license granted to Long Island Lighting Company's (LILCO) Shoreham

plant (see Report 199) was revoked by the Atomic Safety and Licensing Board. The 820-MWe BWR had received NRC permission to begin low-power operation only one week before. The Board revocation was based on the NRC requirement that the plant have a safe source of backup power. An NRC licensing board had bypassed that requirement by recommending that LILCO be granted an exemption. The plant's backup diesel generators are inoperable, but LILCO had submitted a plan involving smaller generators.

LILCO's emergency plan also was rejected by a New York state court, demonstrating Suffolk County's unwillingness to grant the utility authority normally wielded by state and county police in case of emergency. It now is clear that the utility will be unable to implement any emergency plan without the cooperation of local authorities, posing yet another obstacle to Shoreham's operation.

AMPLIFICATIONS

CORRECTION

Three errors appeared in Part 2 of the Optimum Tails Assay article in Report 196 (December 1984).

1. The incremental values of the horizontal axis on Figure 1, page 14, were printed incorrectly, resulting in a misleading curve. The correct figure is reprinted below.

2. In the Appendix to the article, beginning on page 18, the implicit equations contained two errors. In the B' equation, the (Cost Ratio) should be divided by Y, where Y equals $(0.86 + 0.7 \times \text{Tails w/o})$ if the VTAO charge applies. (Y equals 1 if no VTAO charge applies.)

In the S equation, one component of the denominator should be $(0.86 + 0.7 \times \text{Tails w/o})$, instead of $(0.86 - 0.7 \times \text{Tails w/o})$.

For clarification purposes, the entire Appendix is reprinted below, with the correct equations.

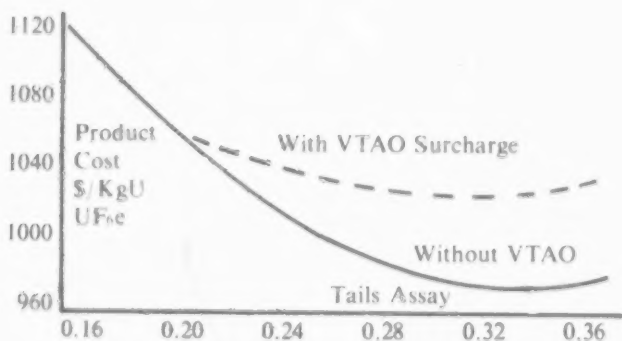


Figure 1. Cost of 3.50 w/o Product as a Function of Tails Assay for Feed at \$50/KgU and Enrichment at \$135/SWU.

Appendix

Tails Assay for Minimum Product Cost with Maximum VTAO Surcharge

The following series of implicit equations can be solved by iteration on a computer or programmable calculator. In this series of equations, the feed is assumed to be 0.711 w/o, and the assays are in units of weight percent, in contrast to the other equations in this article which use assay as weight fractions (weight percent = weight fraction $\times$ 100).

$$A = (\text{Tails w/o} / 50 - 1) \times (0.711 - \text{Tails w/o})$$

$$B' = 4.868883 - (\text{Cost Ratio}) / (0.7 \times \text{Tails w/o} + 0.86) + 0.985780 \times \ln [\text{Tails w/o} / (100 - \text{Tails w/o})]$$

$$S = 0.7 \times \text{SWU Factor} \times (0.711 - \text{Tails w/o})^2 / [(\text{Enrichment w/o} - 0.711) \times (0.86 + 0.7 \times \text{Tails w/o})]$$

$$\text{Tails w/o} = A \times 100 / [(100 - \text{Tails w/o}) \times (B' - S)]$$

The above relationships assume a VTAO credit for tails assays less than 0.2 w/o. As a result, they are incorrect for tails less than 0.2 w/o, and must be adjusted to the lesser of 0.2 w/o or the tails assay for minimum product cost without the credit (Report 195).

URANIUM DEPOSITS IN THE USSR

Introduction

The USSR began developing nuclear power in the late 1940s. Recognized as a favorable alternative for electricity generation, nuclear power plants appeared well-suited for the highly populated regions of western USSR, which are far removed from natural energy resources in Siberia. Construction of the first nuclear generating plant (a 100-MWe liquid graphite reactor) began in early 1950; it was completed and operating in 1954, becoming the world's first nuclear power plant. Nuclear industry development continues in the USSR, although bureaucratic, engineering and construction problems during the mid-1960s, late 1970s and early 1980s have disrupted and delayed the program. The original construction schedule called for a generating capacity of over 50,000 MWe by 1985; actual installed capacity, however, totaled approximately 23,000 MWe at the end of 1984.

A recent announcement by the State Committee for Atomic Energy (GKAE) indicated that nuclear plant construction would be accelerated to increase generating capacity by 40,000 to 60,000 MWe in the mid-1990s, in order to accommodate an annual power growth rate of four percent. If this goal is achieved, approximately 60 percent of the USSR's electricity will be produced by nuclear energy. The program to increase nuclear generating capacity will require the expansion of all phases of the future U_3O_8 requirements, and exploration for new ore deposits along with the development of known deposits has accelerated.

Limited information concerning uranium deposits in the USSR is available from Soviet sources; that information is often limited to deposits which have been developed for industrial purposes. Soviet documentation offers geologic descriptions of certain deposits in considerable detail, while others, thought to be major deposits, are not specified. Ore reserves and percent of uranium content are never cited. Geologic setting and ore genesis are often described, indicating the wide variety of uranium occurrences. The geographic locations of most deposits usually are not described. Association by geologic setting is the principal method Western geologists use to establish location. Still, the location of certain deposits may be only approximate at best. There is even less documentation regarding ore body development and recovery technology.

The *Raw Materials* section of Report 194 (October 1984) examines uranium ores in the Zholtve Vody district of the Ukraine.

Classification of Uranium Deposits

Uranium occurrences in the USSR correspond to many known occurrences in the western world. Significant exceptions are the absence of large-tonnage Precambrian quartz-pebble conglomerates similar to the Witwatersrand Basin of South Africa and the Elliot Lake district of Ontario, Canada, and Proterozoic unconformity-related deposits in the Northern Territory of Australia and the Athabasca Basin of northern Saskatchewan, Canada. However, Soviet geologists remain optimistic that important deposits in both types of geologic environment will be discovered eventually.

Uranium occurrences in the USSR generally are classified by vein-type and hydrothermal mineralization. Vein deposits are associated mainly with intrusive and metamorphic rocks; hydrothermal deposits are associated directly with sedimentary rocks, from sandstones to shales, and coal beds. Uranium deposits are subdivided into four basic series. Each series is further divided into classes and specific types of deposit.¹

1. The *series* of the deposit is determined by geologic position and age, as well as genetic relationship;
2. The *class* of deposit is established by mineralogy, structural form and association with surrounding host rocks;
3. The *type* of deposit depends on the local geologic features controlling mineralization. A total of 16 types of ore deposits have been described. Table 6 lists and briefly describes each type.

Conclusion

Figure 2 illustrates the location of many important uranium districts and production centers in the USSR. Uranium is produced (or has been produced) from all 16 types of deposits listed in Table 6, although the actual importance of each to the uranium supply program is unknown. Certain types of deposits have not contributed to U_3O_8 requirements, while others have served as a main supply. The principal differences between deposits are total tonnage available, contained U_3O_8 , accessibility to mining, and favorable metallurgy.

¹Kazanskiy, V. I., and Laverov, N. P., *Mestorozhdeniya Urana (Uranium Ore Deposits)*—Nedra, Moscow, 1974.

RAW MATERIALS

Table 6

URANIUM ORE CATEGORIZATION IN THE USSR

-
- SERIES A. *Metamorphogenic deposits of ancient platforms.* Uranium mineralization in Precambrian basement intrusives and metamorphic rocks. Tectonic and metasomatic zones contain important vein deposits.
- Type 1. *Iron-uranium mineralization associated with sodium and carbonate-rich metasomites.* Intrusions and folding influenced placement of ore in lower conglomerates, middle hematite-magnetite zones, and upper graphite schists and dolomitic marbles.
 - Type 2. *Uranium associated with sodium-rich metasomatic rocks.* Ore minerals occur in elongated folds at basement contacts. Host rocks are the iron formation, migmatites and mylonites.
- SERIES B. *Endogenic deposits of fold regions.* Ore associated with volcano-intrusive rocks in deep-seated geosynclinal fold belts.
- Class I. *Hydrothermal minerals in andesites-diorites.* Uranium-molybdenum minerals in both rock types, associated with post-orogenic hydrothermal activity.
 - Type 3. *Uranium associated with dikes.* Diorite dikes associated with syenite intrusives cut lower sedimentary rocks. Ore is in conglomerates, sandstones and argillites.
 - Type 4. *Uranium-molybdenum ore in paleovolcanoes and related minor intrusions.* Deposits are in fold-belts of Paleozoic rocks, along faults and folds at intrusive contacts in association with altered sandstone and pyroclastic rocks.
 - Type 5. *Apatite-uranium deposits in paleovolcanoes and carbonate-marine sediments.* Ore occurs in carbonate rocks interbedded with shales and sandstones; ore controlled by faulting and volcanogenic rock sequence.
 - Class II. *Hydrothermal deposits associated with rhyolite-granitic rocks.* Ore is concentrated in volcano-genic depressions and related fault zones; ore formed during post-volcanic hydrothermal activity.
 - Type 6. *Uranium deposits in volcanic depressions.* Ore is of late Paleozoic age, occurring in rhyolite tuffs and breccias associated with caldera tectonics.
 - Type 7. *Molybdenum-uranium deposits in subvolcanic intrusives.* Ore occurs along contact zones of highly fractured and faulted Paleozoic granite and quartz porphyries and intruded andesite.
 - Type 8. *Molybdenum-uranium deposits in volcanic pipes and plugs.* Ore occurs in stock-works and veins in breccia and mylonite zones resulting from volcanic intrusion and accompanying subsidence of Paleozoic basement rocks.
- SERIES C. *Endogenic uranium deposits of reactivated regions.* Hydrothermal uranium deposits occur in trachyte-syenite and andesite-rhyolite rocks along reactivated tectonic zones.
- Class III. *Hydrothermal deposits associated with trachyte-syenite rock formations.* Important hydrothermal uranium deposits occur in sodium-rich intrusives, with thorium in subvolcanic massifs, and titanium in crystalline basement rocks.
 - Type 9. *Thorium-uranium deposits in subvolcanic massifs.* Ore is associated with sodium-rich deep-seated intrusives cutting basement rocks; ore occurs in fracture and breccia zones along major faults.
-

(continued)

Table 6 (continued)

URANIUM ORE CATEGORIZATION IN THE USSR

-
- Type 10. *Titanium-uranium deposits in faulted crystalline basement rocks.* Uranium of hydrothermal origin occurs in tectonic breccias and veins throughout altered and uplifted blocks of crystalline rocks.
- Class IV. *Hydrothermal deposits associated with andesite-rhyolite rocks.* Uranium mineralization occurs in stockworks and veins in andesite-rhyolite rocks filling deep depressions in the basement complex. Molybdenum is a common co-mineral.
- Type 11. *Fluorite-uranium deposits in erosional tectonic basins.* Uranium ore occurs in Paleozoic metamorphic and igneous rocks associated with caldera depressions filled with volcanic flows; the ore forms in veins, stockworks in the older rocks, and as bedded deposits in younger volcanics.
- Type 12. *Arsenic-uranium deposits in erosional tectonic depressions.* Ore minerals are confined to hydrothermally altered sediments filling depressions in granites; basal conglomerates, sandstones and interbedded tuffs are host to ore deposits.
- SERIES D. *Exogenic deposits of younger platforms.* Sedimentary-origin uranium deposits occur in lower Tertiary rocks covering Paleozoic platforms. Most deposits are strataform in nature and considered to be epigenetic.
- Class V. *Epigenetic infiltration deposits.* Ore deposits are associated with carbonate rocks in sedimentary formations, controlled by interaction of descending (and ascending) oxidized and mineral-bearing solutions.
- Type 13. *Vanadium-uranium deposits in carbonates.* Ore is found in Tertiary formations overlying Paleozoic platform rocks. Vanadium is associated where organic material is abundant; carbonates create favorable host in sand-clay beds.
- Type 14. *Selenium-uranium deposits in terrigenous sediments.* Ore has developed in zones of oxidation along formation contacts, usually in folded and faulted sediments covering young platforms. Ore is found throughout the sedimentary sequence, with important ore in sandstones and conglomerates.
- Type 15. *Uranium in coal-bearing sediments.* The coal-bearing depositional sequence is 80 to 200 meters thick, composed of five sequential units deposited on lower Mesozoic rocks. Uranium is absorbed into the coal beds, and occurs in mudstone and sandstone units directly below the coal.
- Class VI. *Sedimentary-diagenetic deposits.* Mineralization is associated with specific sedimentary horizons during the diagenetic process of deposition and lithification.
- Type 16. *Rare earth-uranium deposits in clay.* Uranium mineralization is associated with clay horizons formed by shallow marine deposition; horizons contain rare earth, fish fragments and coalified remnants of plants. Uranium is abundant in fish remains, less so in plant debris.
-

RAW MATERIALS

It is difficult to determine which of the 16 types of deposits are the most important to U_3O_8 supply. It is likely that a number of sources play an important role. Also, many types of deposits found in the USSR, when compared with deposits elsewhere, are low-grade and have questionable recovery economics and difficult metallurgy. Production from molybdenum-uranium deposits in volcanogenic rocks and iron-uranium deposits in the iron-bearing sequence has been consistent in the past and may represent the most important sources of uranium.

Not listed in Table 6 are the uranium-bearing phospho-

rites, oil shales, alkaline granites and carbonatites, all of which contain large quantities of low-grade uranium. Each represents a future source of uranium that can be recovered using other technologies and depending on U_3O_8 requirements. For example, the phosphate deposits in the Zeysk area are now under development, but a plan to recover the uranium contained in the ore has not been announced. The low-grade uranium resources may become an important source of U_3O_8 in the future unless new conventional high-grade deposits are discovered during the early stages of GKAE's current exploration program.

RAW MATERIALS

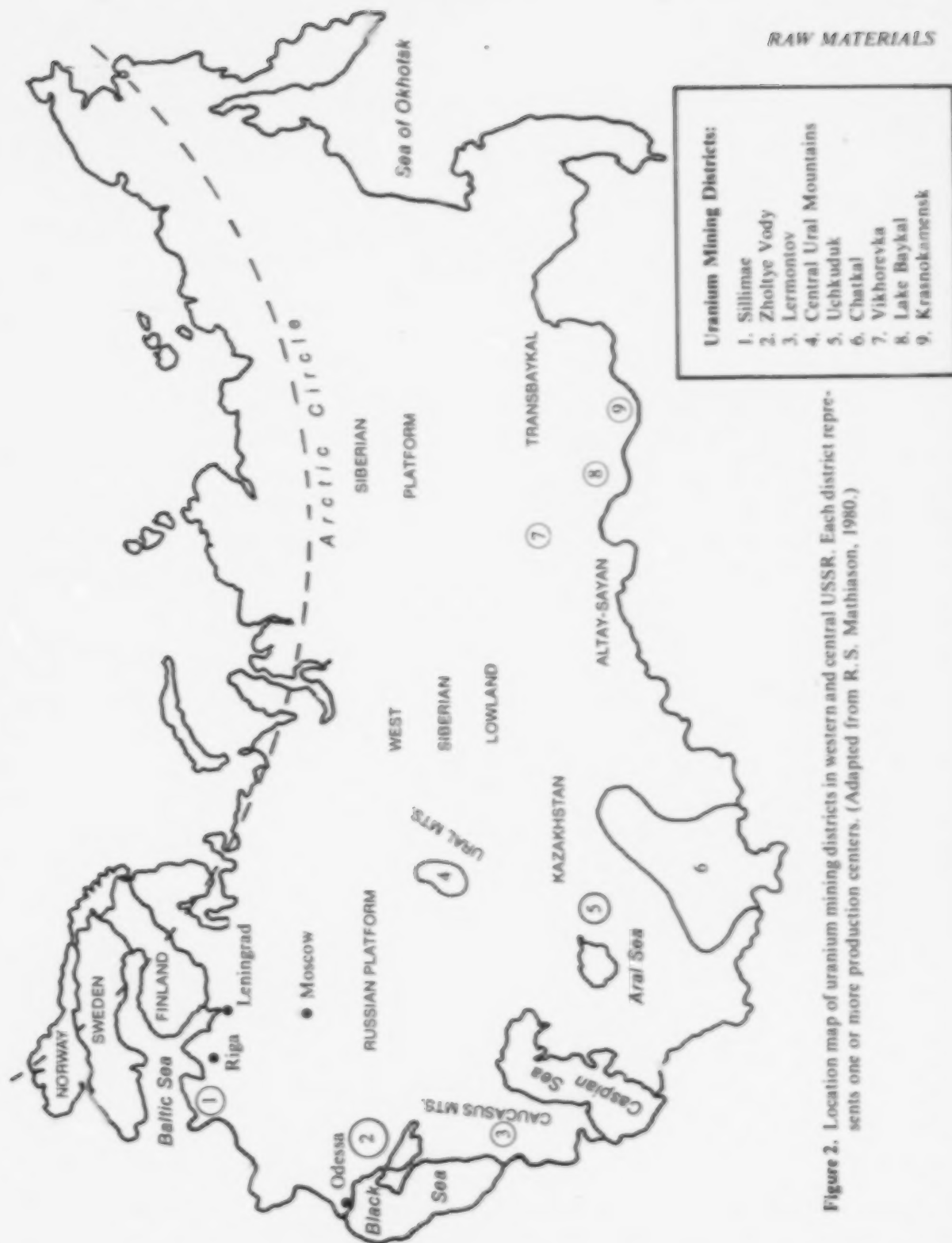


Figure 2. Location map of uranium mining districts in western and central USSR. Each district represents one or more production centers. (Adapted from R. S. Mathiason, 1980.)

NUEXCO

HISTORICAL MARKET DATA

EXCHANGE AND TRANSACTION VALUES SINCE JANUARY 1980 Determined as of the last day of the month indicated



HISTORICAL MARKET DATA

HISTORICAL EXCHANGE VALUES

Determined as of the last day of the month indicated (US Dollars/lb. U₃O₈)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1968	—	—	—	—	—	—	—	6.35	6.35	6.40	6.45	6.50
1969	—	6.35	6.10	6.10	6.25	6.25	6.20	6.20	6.15	6.15	6.15	6.20
1970	6.30	6.30	6.30	6.30	6.30	6.30	6.30	6.20	6.15	6.15	6.15	6.15
1971	6.20	6.20	6.20	6.20	6.15	6.05	6.00	5.95	5.95	5.95	5.95	5.95
1972	5.95	5.95	5.95	5.95	5.95	5.95	5.95	5.95	5.95	5.95	5.95	5.95
1973	5.95	6.00	6.10	6.20	6.45	6.50	6.50	6.50	6.50	6.50	6.75	7.00
1974	7.70	7.90	8.00	9.00	9.50	10.50	11.50	12.00	12.50	14.00	14.75	15.00
1975	16.00	16.00	18.00	20.00	21.00	23.00	24.70	26.00	26.00	28.50	30.00	35.00
1976	32.50	37.00	39.25	40.00	40.00	40.00	40.00	40.40	41.00	41.00	41.50	41.00
1977	41.35	41.50	41.60	41.60	42.00	42.25	42.25	42.25	42.40	42.75	43.20	43.20
1978	42.90	43.25	43.25	43.25	43.40	43.40	43.40	43.10	43.25	43.00	43.25	43.25
1979	43.25	43.25	43.25	43.25	43.25	43.00	42.70	42.70	42.20	42.20	41.00	40.75
1980	40.00	38.00	35.00	32.00	32.00	31.50	31.50	30.00	28.50	28.00	28.00	27.00
1981	25.00	25.00	25.00	25.00	25.00	24.25	23.50	23.50	23.50	23.50	23.50	23.50
1982	23.00	23.00	22.50	20.75	20.50	19.25	18.25	17.00	17.00	17.50	19.75	20.25
1983	21.50	21.75	22.25	23.25	23.50	23.50	24.00	24.00	24.00	23.50	22.50	22.00
1984	20.50	17.50	17.00	17.75	17.75	17.50	17.50	17.50	17.50	16.00	15.50	15.25
1985	15.00	15.00	15.00									

HISTORICAL TRANSACTION VALUES

Determined as of the last day of the month indicated (US Dollars/lb. U₃O₈)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1976	—	—	—	—	39.60	39.70	39.70	40.40	40.30	40.60	40.70	40.70
1977	41.30	41.30	41.40	41.50	42.80	42.90	43.00	42.60	42.50	42.80	42.90	42.90
1978	43.10	43.30	43.70	43.60	43.60	43.20	43.30	43.40	43.40	43.60	43.40	43.70
1979	43.60	43.80	43.70	43.40	43.60	43.70	43.70	43.60	43.60	43.60	43.50	42.30
1980	42.00	39.30	38.60	38.40	37.90	37.60	37.30	31.60	30.60	29.00	28.70	27.70
1981	27.20	27.20	27.00	25.70	25.70	24.50	24.40	24.30	23.90	24.10	24.10	24.00
1982	24.00	23.70	23.40	22.60	22.70	21.50	20.30	19.10	17.30	17.00	17.55	18.80
1983	19.35	20.00	21.35	21.40	22.35	22.45	23.50	23.60	23.65	23.65	23.85	23.85
1984	23.05	22.50	19.25	17.90	17.00	16.50	16.60	16.40	16.55	16.05	15.90	15.90
1985	16.20	15.70	15.05									

HISTORICAL CONVERSION VALUES

Determined as of the last day of the month indicated (US Dollars/lb. U as UF₆)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1981	1.20	1.20	1.20	1.40	1.15	1.15	1.15	1.10	1.10	1.10	1.20	1.20
1982	1.20	1.20	1.20	1.20	1.00	1.00	1.00	0.90	1.10	1.60	1.45	1.45
1983	1.20	1.40	1.40	1.20	1.20	1.20	1.10	1.10	1.00	0.60	0.60	0.60
1984	0.60	0.30	0.80	0.80	0.80	0.00	0.00	0.80	1.00	1.00	0.80	0.80
1985	1.00	1.00	1.00									

NUEXCO

GOVERNMENT STATISTICS

AUSTRALIA

	Price Index of Materials Used in Manufacturing Industry—All Groups ¹ (1969=100)	Award Rates of Pay Indexes Australia—Adult Males In Mining Wage and Salary Earners, Weekly Rates ² (1976=100)
1983 Avg.	401.2	181.8
Nov 1983	395.5	188.3
Dec 1983	399.2	188.1
Jan 1984	399.2	188.6
Feb 1984	402.5	188.5
Mar 1984	403.9	188.3
Apr 1984	404.2	196.2
May 1984	403.8	197.0
Jun 1984	404.9	197.0
Jul 1984	408.5	197.0
Aug 1984	413.3	197.0
Sep 1984	412.1	197.0
Oct 1984	408.6	197.0
Nov 1984	407.2	197.0
Dec 1984	—	197.0

P = Preliminary R = Revised since last month

CANADA

Wage-earner Data: Average Hourly Earnings (C\$) ²							
	Industry Selling Price Index: Manufacturing ¹ (1971=100)	Uranium Mines (SIC 057)	Metal Mines* (SIC 051-059)	Mines, Quarries and Oil Wells ³ (SIC 051-099)	Primary Metal Industries Non-ferrous ⁴		Chemicals and Chemical Products ⁵ (SIC 372-379)
					(SIC 296)	(SIC 298)	
1983 Avg.	298.8	—	—**	14.30	—	—	11.17
Jan 1984	305.4	17.74	15.27	14.74	11.91	10.84	11.69
Feb 1984	306.6	17.78	15.59	14.90	12.04	10.82	11.51
Mar 1984	308.7	18.05	15.52	14.82	12.14	10.84	11.58
Apr 1984	310.5	18.06	15.83	15.10	11.96	10.34	11.63
May 1984	310.6	18.48	15.64	15.06	12.11	10.16	11.55
Jun 1984	311.0	18.08	15.48	14.80	12.38	10.40	11.66
Jul 1984	312.7	17.81	15.72	14.92	12.53	10.18	11.82
Aug 1984	312.7	17.24	15.36	14.92	12.44	10.34	11.78
Sep 1984	312.3	17.68	15.96	15.34	12.51	10.52	11.90
Oct 1984	312.3	17.64	16.15	15.26	12.69	10.56	11.96
Nov 1984	313.6	18.04	16.13	15.43	12.47	10.51	11.96
Dec 1984	314.2R	17.95R	16.39R	15.60R	12.16R	10.40R	11.99R
Jan 1985	315.6R	18.20P	16.03P	15.52P	12.32P	10.89	12.07P
Feb 1985	316.0P	—	—	—	—	—	—

P = Preliminary R = Revised since last month

For annual averages prior to 1983, and for notes pertaining to these statistics, see pages 23-26 of Report 190 of June 1984.

*The 1980 average for Metal Mines was incorrectly reported as 10.59. The correct average is 10.58 (see Report 190).

**Two different methods were used in the 1983 "Metal Mines" category in reporting survey data, and Statistics Canada did not publish a 1983 average. The March 1983 figure for the old method was 14.73 and for the new method was 14.84. The published average for 1983 in Report 190 was a Nuexco calculation based on the available monthly statistics for 1983 with the exception of the March figure, where only the 14.84 value was taken into account.

GOVERNMENT STATISTICS

REPUBLIC OF SOUTH AFRICA

	Average Declared Working Costs per Metric Ton of Gold Ore Milled (Rand) ¹	Tonnage-Weighted Index of Average Working Costs per Metric Ton of Gold Ore Milled (March 1982=100) ²	Consumer Price Index ³ (1975=100) ⁴	Producer Price Index All Groups ⁵ (1975=100)	Total Employment in Mining and Quarrying (Code 35) ⁶	Total Salaries and Wages in Mining and Quarrying (1,000 Rand) (Code 40) ⁶
1983 Avg.	51.87	115.0	262.2	274.8	696,579	3,644,772
Jan 1984	—	—	274.7	283.3	689,807	326,619
Feb 1984	—	—	278.4	286.5	702,553	335,906
Mar 1984	55.30	123.1	281.9	288.0	715,628	342,332
Apr 1984	—	—	286.1	290.2	712,963	327,550
May 1984	—	—	288.3	292.6	710,040	327,937
Jun 1984	56.95	126.2	291.2	295.3	717,009	347,121
Jul 1984	—	—	295.1	296.0	717,121	369,964
Aug 1984	—	—	297.0	300.8	721,905	361,357
Sep 1984	60.64	133.2	299.9	304.1	721,470	359,218
Oct 1984	—	—	303.7	308.7	717,865	363,755
Nov 1984	—	—	307.4	312.8	717,396	369,771
Dec 1984	62.92	138.6	309.4	315.9	701,198	365,234
Jan 1985	—	—	177.1*	166.6*	—	—
Feb 1985	—	—	182.8*	—	—	—

*The basis for calculation for these indices has been revised to January 1980 = 100.

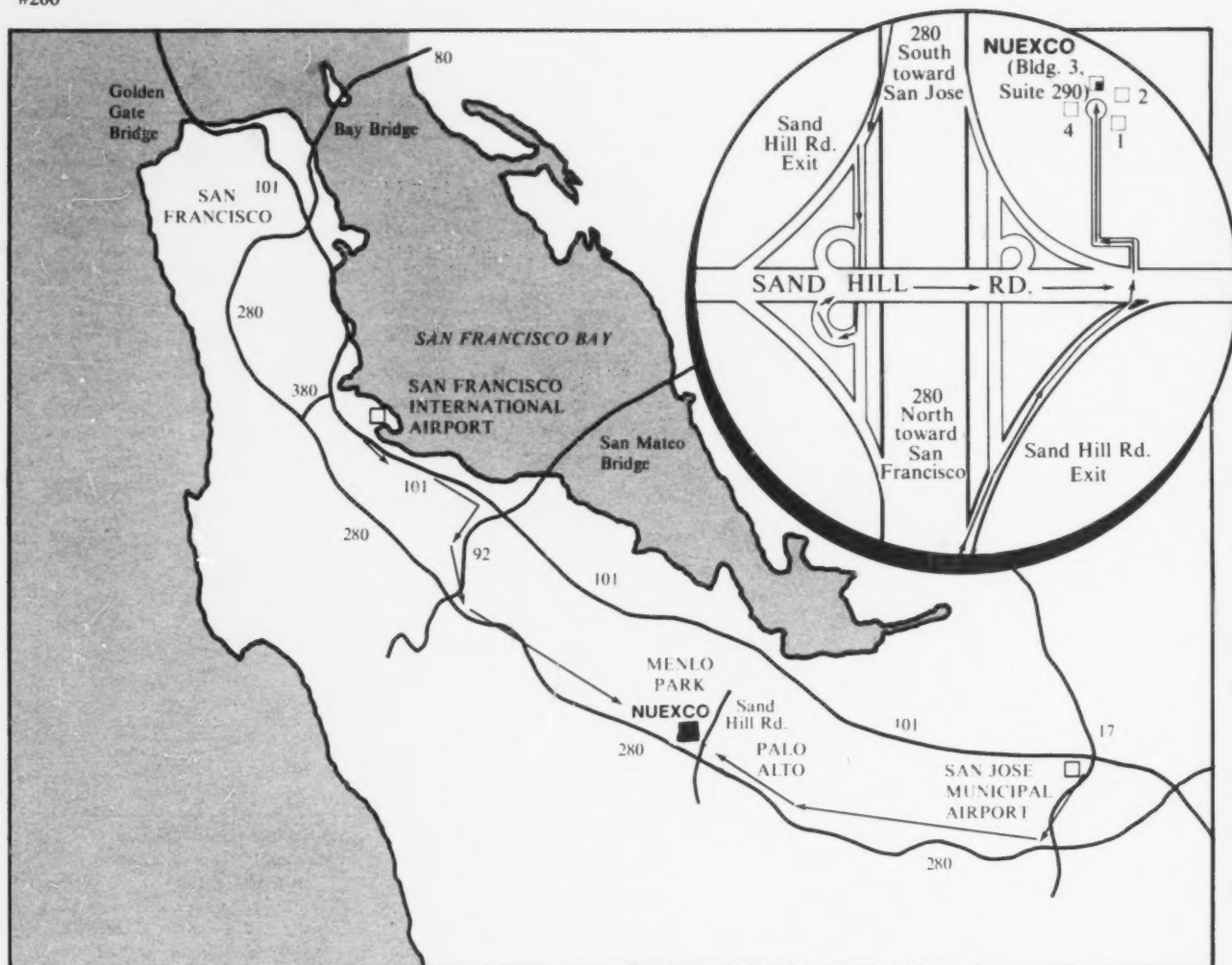
UNITED STATES

	Producer Price Index ¹		Consumer Price Index ² (1967=100)	GNP Implicit Price Deflator ³ (1972=100)	Gross Average Hourly Earnings of Production or Non-supervisory Workers (US\$) ⁴			
	Industrial Commodities (1967=100)	All Commodities (1967=100)			Metal Mining (SIC 10)	Primary Non-ferrous Metals (SIC 333)	Chemicals and Allied Products (SIC 28)	Electric and Electronic Equipment (SIC 36)
1983 Avg.	315.8	303.1	298.4	215.63	12.57	13.43	10.59	8.65
Dec 1983	318.4	306.1	303.5	218.53	12.75	13.33	10.90	8.84
Jan 1984	319.1	308.0	305.2	—	12.67	13.38	10.91	8.88
Feb 1984	320.6	308.9	306.6	—	12.81	13.34	10.90	8.86
Mar 1984	321.9	311.0	307.3	220.58	12.85	13.33	10.95	8.88
Apr 1984	322.5	311.4	308.8	—	12.91	13.30	10.97	8.89
May 1984	323.3	311.7	309.7	—	12.99	13.37	11.02	8.89
Jun 1984	323.9	311.4	310.7	222.40	12.96	13.40	11.03	8.91
Jul 1984	324.0	312.0	311.7	—	13.02	13.36	11.12	8.95
Aug 1984	323.5	310.9	313.0	—	13.10	13.51	11.13	9.00
Sep 1984	322.3	309.5	314.5	224.57	13.20	13.39	11.23	9.08
Oct 1984	323.2	309.4	315.3	—	13.23	13.53	11.32	9.09
Nov 1984	323.8	310.4	315.3	—	13.23	13.76	11.35	9.15
Dec 1984	323.0	309.9	315.5	226.10	13.28R	13.66R	11.37R	9.27R
Jan 1985	323.2	309.8	316.1	—	13.26P	13.73	11.43R	9.29R
Feb 1985	322.5	309.2	317.4	—	—	—	11.40P	9.30P

P = Preliminary R = Revised since last month

For annual averages prior to 1983, and for notes pertaining to these statistics, see pages 23-26 of Report 190 of June 1984.

NUEXCO



DIRECTIONS TO NUEXCO'S CORPORATE OFFICES

From San Francisco Airport:

1. Take U.S. 101 south towards San Jose.
2. Continue on U.S. 101 seven miles to Route 92 exit.
3. Take Route 92 west towards Half Moon Bay.
4. Continue on Route 92 five miles to Interstate 280 exit.
5. Take Interstate 280 south towards San Jose.
6. Continue on Interstate 280 ten miles to Sand Hill Road exit.
7. Take Sand Hill Road east towards Menlo Park (go under Sand Hill Road overpass, circle 270° to cross Interstate 280 on overpass heading east).
8. Turn left at first traffic light.
9. After turning left, take second left and follow signs for 3000 Sand Hill Road.
10. We are in Building 3, Suite 290, on the second floor.

From San Jose Airport:

1. Take Highway 17 south towards Santa Cruz.
2. Continue on Highway 17 five miles to Interstate 280 exit.
3. Take Interstate 280 north towards San Francisco.
4. Continue on Interstate 280 six miles to Sand Hill Road exit.
5. Take Sand Hill Road exit.
6. Proceed through both sets of traffic lights.
7. Take first left after second traffic light and follow signs for 3000 Sand Hill Road.
8. We are in Building 3, Suite 290, on the second floor.

Note: Distances are approximate.

HOTELS

Hilton Inn, San Francisco Airport, (415) 589-0770.
Hyatt House, 1740 North 1st Street, San Jose, (408) 298-0300
Holiday Inn-Palo Alto, 625 El Camino Real, Palo Alto, (415) 328-2800
Rickey's Hyatt House, 4219 El Camino Real, Palo Alto, (415) 493-8000
Fairmont Hotel, 950 Mason Street, San Francisco, (415) 772-5000

RESTAURANTS

L'Auberge, 2826 El Camino Real, Redwood City, (415) 365-3735
or (415) 365-9623
Dal Baffo European Cuisine, 878 Santa Cruz Avenue, Menlo Park, (415) 325-1588
Velvet Turtle, 325 Sharon Park Drive, Menlo Park, (415) 854-3813
Ming's of Palo Alto (Chinese), 1700 Embarcadero Road, Palo Alto, (415) 327-0771
Hugo's Market Restaurant (at Hyatt), 4219 El Camino Real, Palo Alto, (415) 493-8000

NUEXCO

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